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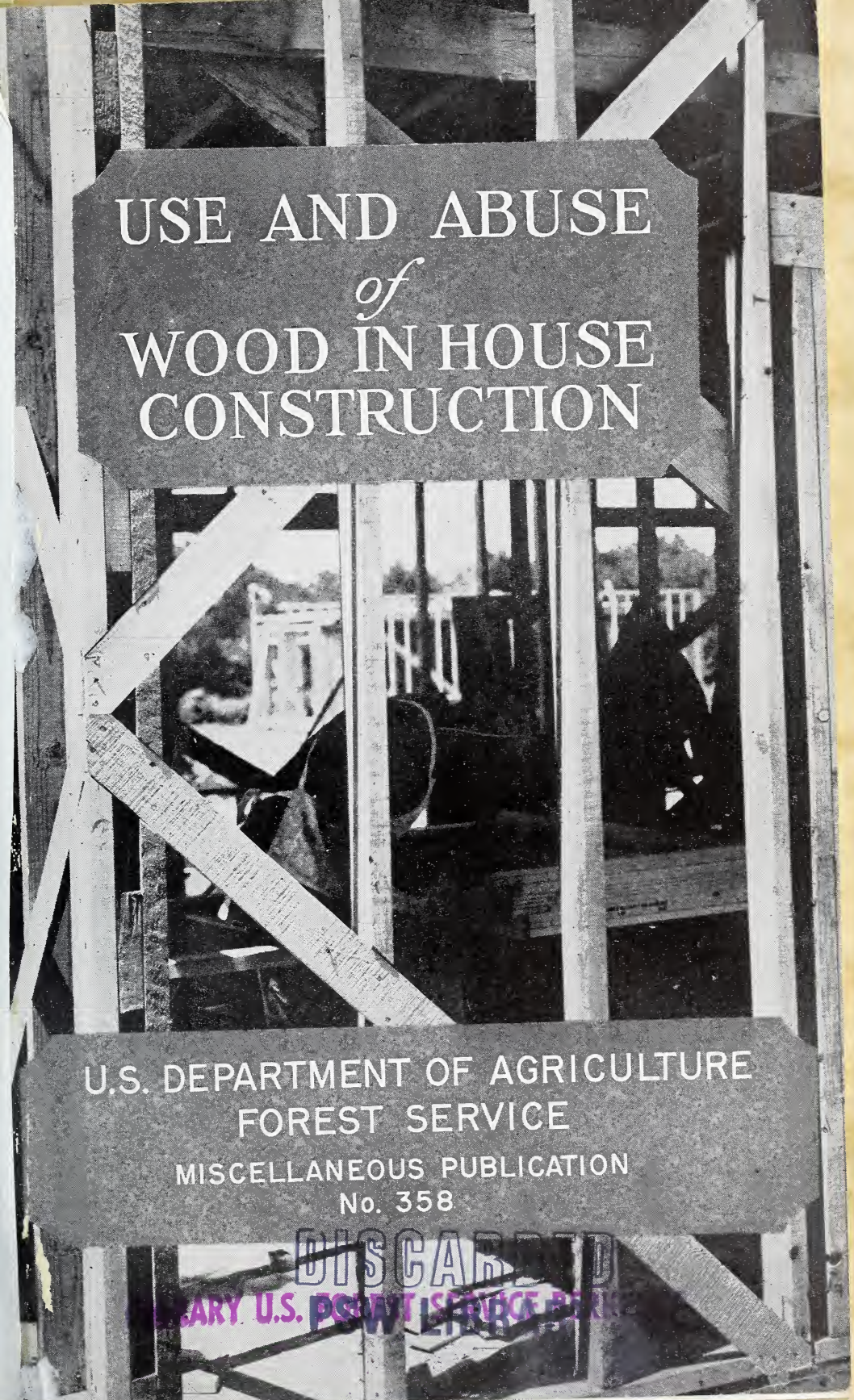

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USE AND ABUSE OF WOOD IN HOUSE CONSTRUCTION

By

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AND

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Forest Products Laboratory
Forest Service

MISCELLANEOUS PUBLICATION NO. 358
U. S. DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.
1939

Introduction

THE BUILDING OR BUYING of a house involves for the average person a large investment and one for which he is entitled to good construction and full value for every dollar expended. Most people plan the purchase of their houses many months in advance—reviewing past experiences, posting themselves on features of design, consulting with other owners, and then weighing all the evidence. The actual construction of the house, of course, requires the services of trained workmen and experienced supervision, which are readily available to the prospective home owner regardless of his own experience.

Home building is a fascinating undertaking in which careful planning and consideration for features of enduring worth will yield large returns in the form of lasting satisfaction. To build these values into a home is not an insurmountable difficulty. It is a matter of selecting, through proper design, the features that secure these values and then of taking care that they are properly installed. Regardless of whether the responsibility for the complete job is placed in the hands of competent professional advisers or borne wholly by the individual, much mental ease is derived from one's own knowledge that the house is well-built. It is also a matter of cold business discretion to make sure that a house is so constructed that it will not present annoying problems of repair and maintenance. It is the purpose of this publication to assist in identifying good construction where lumber and other forest products are used.

To find where guidance in the use of wood in current building is particularly needed, the Forest Products Laboratory [1] recently inspected 600 houses under construction in 20 key communities in Northern, Southern, and Eastern States. This publication deals

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

principally with those construction features that the inspection showed were most likely to be misunderstood or neglected. It concerns carpentry and the application of structural principles, as well as the quality of wood used therein, rather than finish or decoration. Photographs of actual current building practices taken during the inspection furnish the principal subject matter.

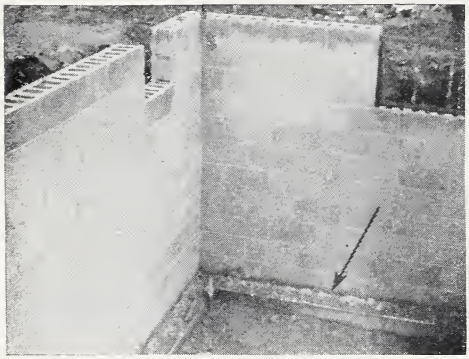
Today's building methods differ materially from those of the past; sometimes, as illustrated in this publication, they are not so good but more often they are markedly better. Lumber obtainable today is machined better, graded better, and seasoned better than formerly, and a wider selection of species and items is available. The net result should be a much better and more comfortable house than was formerly possible. In addition, the Laboratory's examination of houses now being built discloses strong forces at work to protect the home buyer against the pitfalls of shoddy construction. This fact should furnish some assurance to the home-building and home-buying public. An outstanding example of better construction was found in all houses being financed with Federal Housing Administration guaranteed loans.

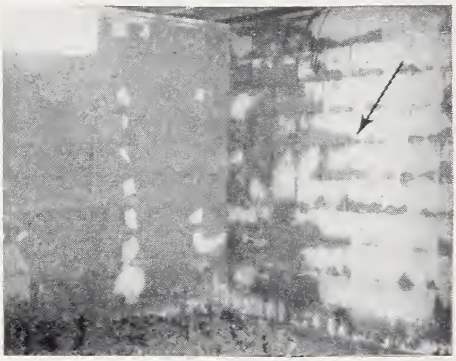
How the guiding principles emphasized in this publication are to be applied in the inspection of the particular house with which the reader is concerned must be left largely to the individual's ingenuity and resourcefulness. If the house is still to be built or is being built the procedure is simple. If the house is already completed the application is much more difficult because many of the features are partly covered, but one can still see much from the outside, from the basement, and from the attic. The better contractors and workmen have been practicing good construction for years. An examination of houses under construction in a community in the light of the details pictured here should serve as an aid in the selection of a competent builder.

Some technical details, such as the size of joists and rafters required for different spans and loads, cannot be dealt with in this simple, brief publication. Such details can best be learned from the structural-design information available at the office of the local lumber yard, contractor, or architect.

Foundations

Desired results in the use of wood in house construction are conditioned first of all on proper foundations, the essential features of which are frequently impressed too late upon the owner's mind. Settling walls and wood-rotting dampness in basements are the glaring consequences of poor foundations. Less conspicuous but very important in some localities is termite attack. In regions subject to wind damage the house should be anchored to the foundation by $\frac{5}{8}$-inch bolts, spaced 6 feet, and extending down 2 feet into solid masonry walls. Better anchorage is required for hollow masonry.

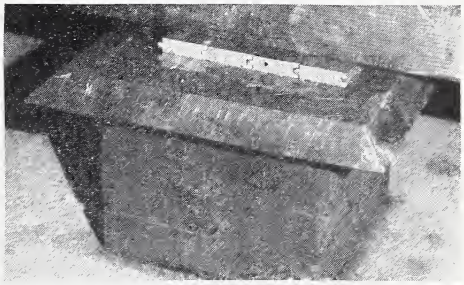




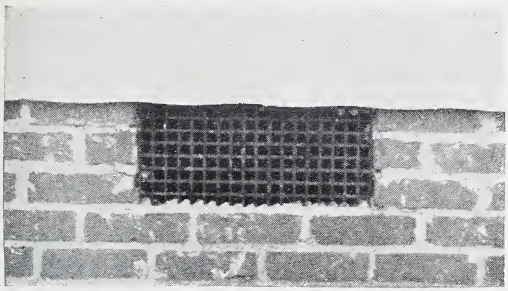
Block walls outnumber poured concrete in many cities. Proper footings (left), to prevent unequal settlement, are important to each type, but particularly to block walls, and should be laid below the frost line. Poorly mortared joints, lack of drainage, and absence of exterior waterproofing result in leaking walls and wet basements (right).

The rough, uneven top surface of the concrete foundation necessitates that all joists as well as headers, when no sill plate is used, be carefully leveled and wedged. Too frequently only a few joists are wedged, the space between concrete and header is not properly filled, and air leakage chills the basement and the floor above. The space between sill and wall should be filled with cement grout

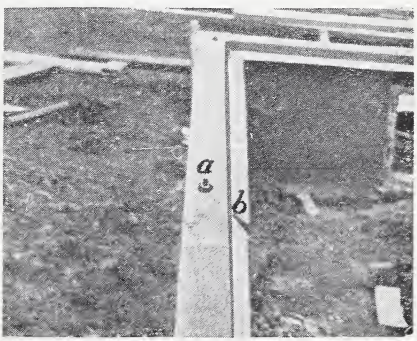
In the Southern States houses commonly have partial or no basements. The South in large measure has learned the importance of unobstructed ventilation underneath the house and the advantages of barriers against termites. The North has yet to learn how to provide sufficient ventilation under houses with no basements to prevent decayed sills and still have warm floors in the winter.



Carelessly constructed piers (left) deteriorate rapidly and are responsible for sagging and twisting of frames of many houses in the South. The absence of metal shields leaves the house exposed to the attack of termites. Sturdy sills on piers (right) can take the place of continuous-bearing foundation walls. A properly placed metal shield on top of the pier in termite areas prevents insects working up from the ground; sills which have been treated under pressure with a wood preservative, are added protection against both decay and termites.



Enclosed foundations for houses with partial or no basement require ample ventilation to avoid decay. Screened vents totaling 3 percent of the house area are best, with a thoroughly insulated floor. One small ventilator in each wall is hardly enough in the damp South. Adjustable windows are frequently forgotten and ventilation thus may be neglected.

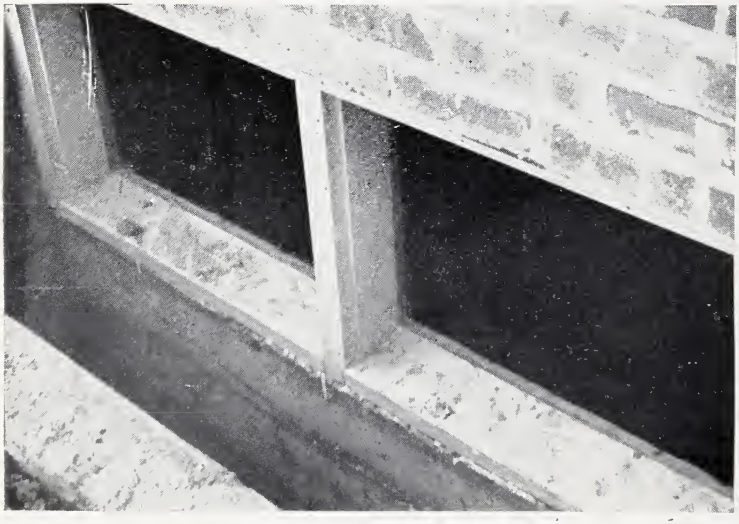


Sills bolted (a) to the foundation, with metal termite shields between sills and concrete, and bolt holes sealed with coal-tar pitch, constitute good construction in the South. Termite shields having short overlaps without solder or crimping (b) are usually ineffective.

In the Basement

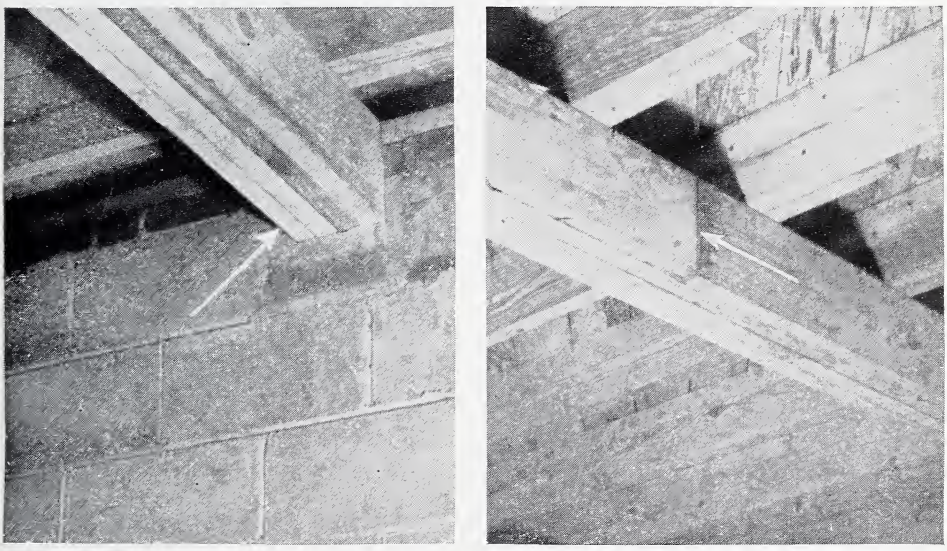
Posts, girders, and window frames of wood are used extensively in some communities; in others they are the exception. Wood has rendered good service in the past in such parts, when construction faults have been avoided, and will in the future if provision is made to keep the wood dry and prevent termite attack. All untreated wood should be insulated from the earth (i. e., from decay and termite attack) by masonry.

No outward pitch to the window sill and two single frames side by side instead of a double one may result in moisture-holding pockets and air leakages that good construction avoids. Joints between frames should be protected with a covering strip.



A good window guards against damp joints and corners and accumulations of leaves and dirt which gather dampness adjacent to the sill. Even so, most basement windows require all-heart stock of decay-resistant wood or wood treated with preservatives.

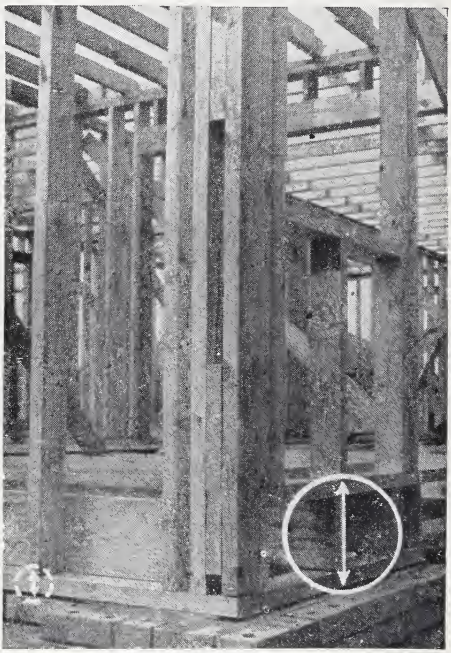
Allowing a wood post to bear directly on a concrete basement floor (left) invites decay. Embedding the post in the concrete is still worse. Wood blocks or shims are of no help. A concrete base block resting on a cement footing and extending above the final floor level (right) provides necessary drainage, substantial bearing surface, and protection from fungus or termite entry from the ground.



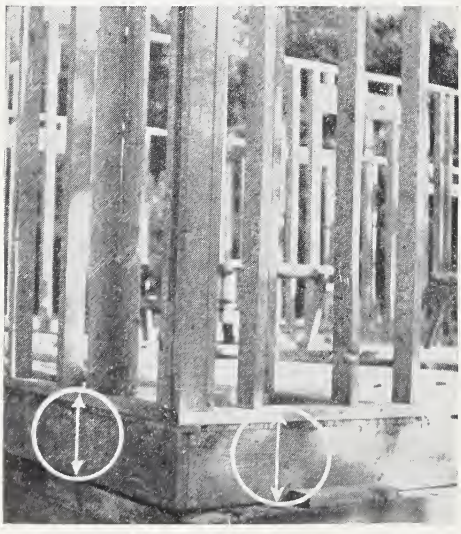
Embedding the ends of girders in masonry or concrete walls (left) is not good practice unless the point of contact is well above the outside grade line so that the concrete does not become damp and transmit dampness to the wood. Where necessary to seal wood in a wall close to the grade line, preservative-treated or all-heart stock of a naturally decay-resistant wood should be used. Girders built up by nailing planks together should never contain splices at or near the middle of the span (right). It is always good practice to place the joint over a post or division wall.

The Skeleton Frame

Framing methods involve some technicalities, but none too complex for the layman to grasp after a little thought. The difficulty is that the framing is soon covered; and only by peeking in dark corners around joists and sills in the basement and under eaves and floor in the attic, can the householder get any idea of how well the work was done. Wood shrinks most crosswise of the grain and only negligibly lengthwise. Unbalanced shrinkage, leading to plaster cracks in walls, occurs when the studding of one side wall rests on the foundation plate and the other side wall on the joists. Balanced shrinkage may be obtained by avoiding "on-edge" material in or under the wall or by using the same amount all the way around.



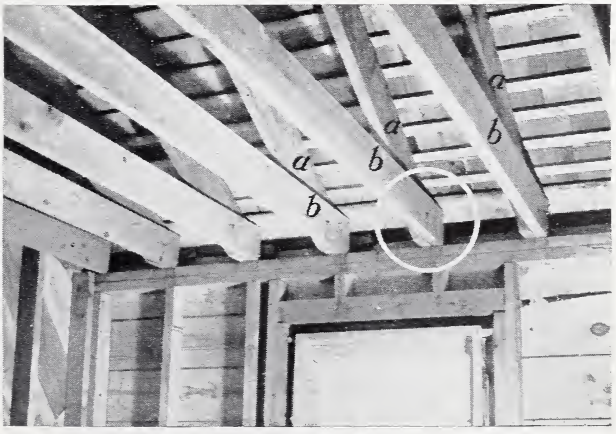
The wall resting on the 10-inch joists (large arrow) will settle more than that resting on the 2-inch plate (small arrow) because of the larger amount of crosswise grain in the joists. Such differentials, found also in the framing of stair wells and elsewhere, must be avoided to prevent settling. The modern braced or balloon types of framing accomplish this by carrying all studs in both interior and exterior walls to a plate or other main support under the joists, as indicated by the small arrow.



A third type of framing, the platform type, rests all studs on a plate on top of the platform floor (left). All three of these types have their advantages. The important thing is not to mix them, as has been done in the illustration above.

Direct contact between chimney and framing (left) is not good practice. The present universal use of tile flue linings reduces the fire hazard tremendously, but the builder should not rely on this for complete protection. Framing kept 2 inches from the chimney (center) and insulated therefrom is a requirement of most building codes and provides a desirable margin of safety. Framing methods which bring wood members close to the inner connections between the fireplace and the chimney (right) introduce a high fire hazard, since even good mortar burns out. Several courses of brickwork should actually intervene between the throat of the fireplace and the framing. Tile flue linings in the chimney are of no avail in the connecting flue between the fireplace and the chimney.

A spacing of rafters (a) different from that of the ceiling joists (b) often results in inadequate tying together of roof, walls, and frame. Unequally spaced joists and rafters should provide for the spiking of at least every third joist to a rafter.



Equally spaced rafters (a) and ceiling joists (b) can be spiked at every rafter and both spiked to the plate above the studs, thus tying the walls together and making in effect a truss of roof framings.

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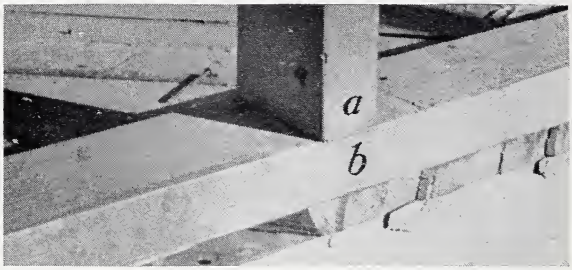
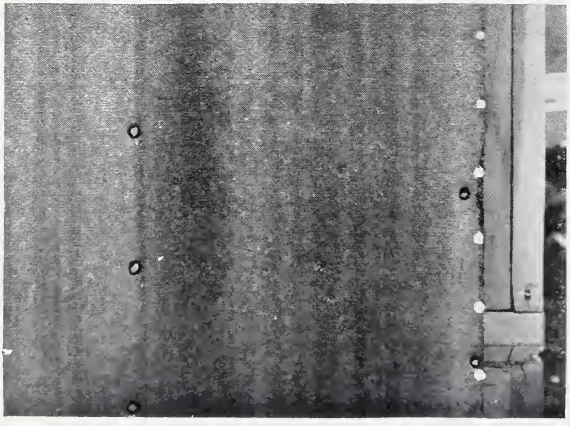
Nails

Skimping on the number of nails means increased maintenance costs. It reduces labor costs, but not enough to be worth while. Skimpy nailing is apt to go with other skimps, and is an unfavorable index of quality of workmanship.

Three twentypenny nails to each joist through the header (a) is the common practice in well-built houses. In most communities some houses will be found with only two nails to the joists but that is not the practice of the majority of builders and the adequacy of such nailing is questionable. An additional nail adds little to the cost but greatly to the strength of the joint.

Two eightpenny nails through each side of the studding (a) to the plate (b) are common. The use of fewer nails to a stud is questionable. Two nails to fasten sheathing boards, subflooring, and roof sheathing to the framing is almost universal practice for boards under 10 inches wide.



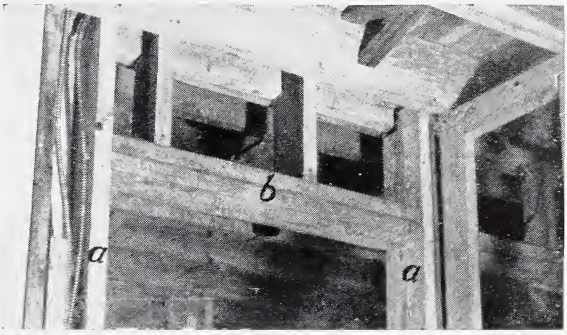


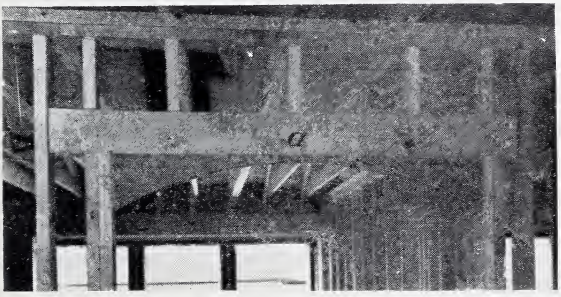
Sheet sheathing materials, to impart high rigidity to the walls should be closely nailed, especially at the edges. The manufacturers may specify the desirable nail spacing (white spots near edge of sheathing), but too frequently the builder cuts down the nailing and much of the bracing action of the wide sheets is lost.

Around the Openings

THE FRAMING of openings is an important factor in the occurrence of plaster cracks over and at the corners of doors and windows and in the degree to which sticking occurs. The character of the framing around the openings is a good yardstick for measuring the quality of the framing of the building as a whole.

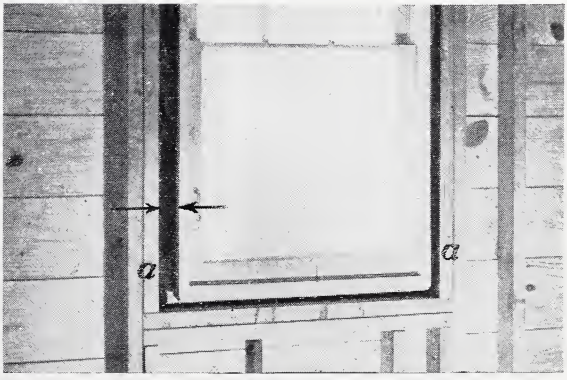
A well-framed single door opening has a double header above the doorway and doubled studding at the sides. Single studs (a) and headers flat (b) should be avoided. Headers placed on edge rather than flat are twice as strong and four times as stiff. In actual practice flat and edge headers occur about equally.





The height of the piece over an opening (a) should increase proportionately with the width of the opening. If two 2 by 4's on edge are required for a 3-foot opening, the same rigidity for a 6-foot opening will require two 2 by 8's.

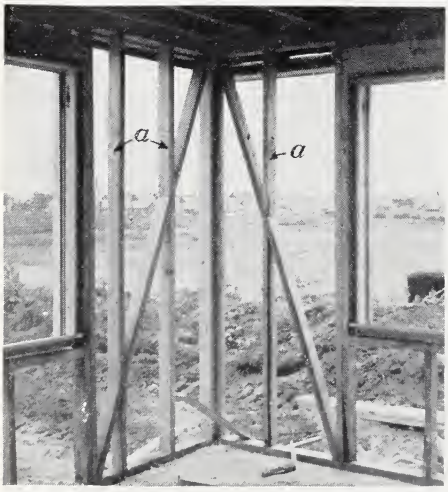
A window properly framed has double studs (a) at the sides, as illustrated, or the inner studs may extend through to the floor. To guard against excessive heat losses the space around the window frame should be carefully filled with good insulating material even though special insulation is not used in the wall itself.



Braces

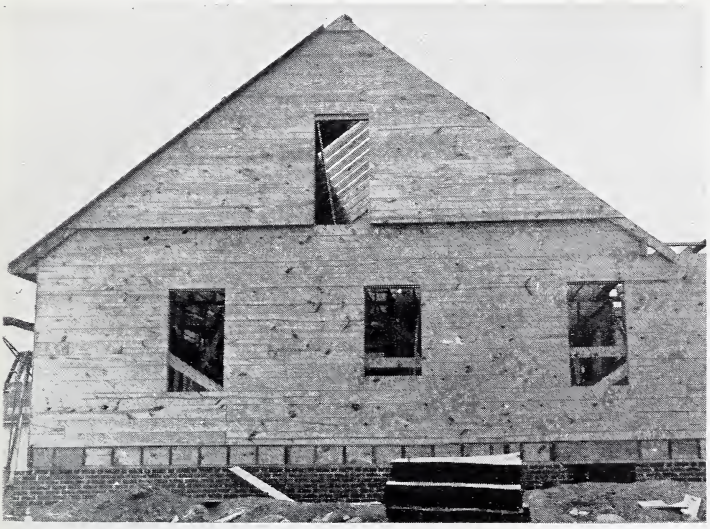
It is what the engineer terms rigidity or stiffness rather than the breaking strength that should be most closely watched to avoid unsatisfactory service in the form of cracks and sticking doors and windows. Most houses are strong enough when well nailed, but many are not rigid or stiff enough. Little or no increase in the amount of material used is necessary to produce a rigid rather than a flimsy wall. High rigidity cannot be obtained with horizontal sheathing without the use of bracing. Laboratory tests show that bracing increases the stiffness of a horizontally sheathed wall, depending on the type of brace used, from one and one-half to three times that of the unbraced wall. The mere addition of diagonal pieces in the corners does not constitute good bracing. Pieces carelessly inserted and toe-nailed between the studs are of little value.

Short braces made necessary by openings or other obstructions should run from the ceiling plate to the corner post and other braces should run from corner post to floor plate. The bracing on the left wall is good; that on the right wall, made of short pieces (a), is poor. A well-braced wall has pieces extending from ceiling to the floor, the studs being notched to receive them.



Braces should be as long and as near a 45° angle as possible. Efficient bracing can be obtained with 2 by 4's extending as in the picture from the ceiling to the floor with studs (a) toenailed to the brace.

Sheathing serves not only as covering and as the base for finished siding, but adds to the stiffness and strength of the house and helps to bring and hold studs in proper alignment. There are two ways of putting on wood sheathing, namely, horizontally and diagonally. Horizontal sheathing is weaker and much less rigid than diagonal sheathing but easier and cheaper to install. Diagonal sheathing increases the stiffness of an unplastered wall, according to experimental tests, from four to seven times compared with unbraced horizontal sheathing. Diagonal sheathing is not commonly found in most communities but prevails in some southern and a few northern cities.

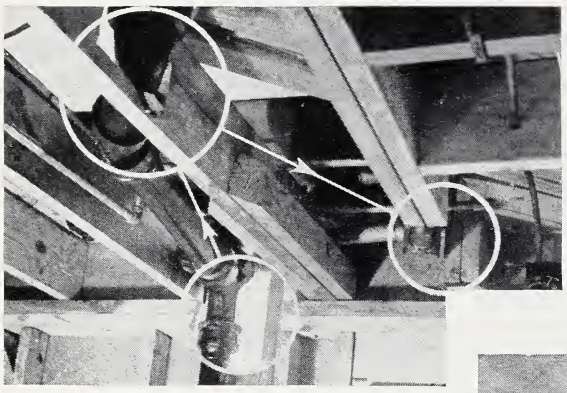


Horizontally sheathed houses should be diagonally braced unless they are of the low squat type with comparatively few openings. Otherwise, they will lack the rigidity desired in a good house, especially in the regions subject to high winds.

When diagonal sheathing extends down over the header joist and is nailed there, it ties the wall to the floor system. When the floor system is in turn bolted to the foundation wall, the total effect is high resistance to windstorms.

Cutaways

An excellent framing job is often spoiled by workmen who come into the building after the carpenters have finished. These fitters come to install piping, heating ducts, and the like, and if the location for this equipment is not carefully planned in advance the workmen find structural members in their way. When this occurs they cut or otherwise weaken the woodwork to clear the way for the pipes.



Here the double plate in the outside wall is cut through and a joist is practically cut away in the middle and at the end with crude and ineffective reinforcement. Further, the double joists supporting a partition above have been severed with no attempt at repair.

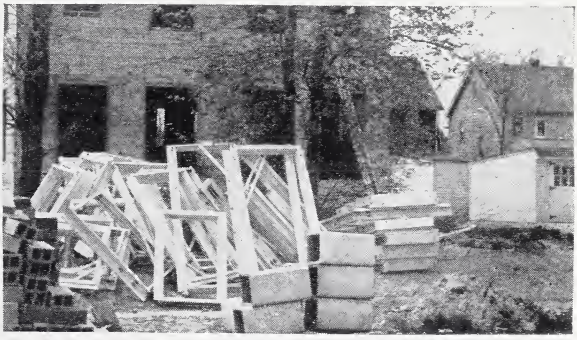
Advance planning minimizes likelihood of settling floors under heavy bathroom fixtures. Provide space for large drain pipes without excessive cutting by using 2-by-6's instead of 2-by-4's as studding in the enclosing wall and tying to the plate on the wall with a good 2-by-4 brace. The cut ends of the subfloor above are here well supported.

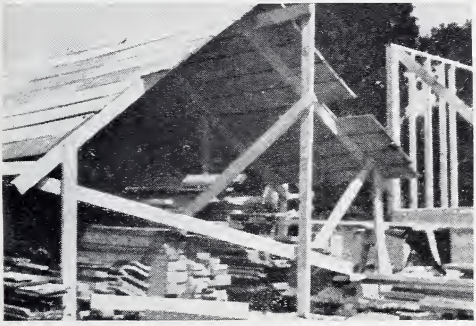
Good framing for heating ducts and drain pipes entails use of extra studs inserted to support members that have been cut through.

Rains During Building

Some of the wetting that a house gets during construction is unpreventable. The unpreventable part as a rule does relatively little damage because surface wetting of the open house framing usually drains and dries off rapidly. However, the wetting of finish items, such as siding, frames, and the like, does a great deal of damage. It can easily be prevented but frequently is not. The exposure of interior finish and flooring to actual rain is universally avoided. On the other hand, these materials absorb much moisture if brought indoors before the house is ready for them, particularly when the plaster is still damp.

Window frames worth buying are worth protecting from the weather until they are fitted. Often good manufacture is nullified by unnecessary exposure. Putting them under cover is almost as easy as leaving them outside, and far better.



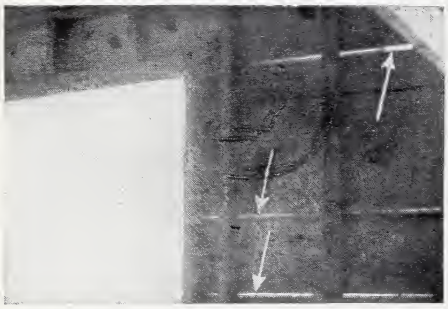


Comparatively few builders take the few minutes required to erect a rough shelter to protect the lumber from rain and sun, or have the forethought to build the garage first and use it for lumber storage. Is there any doubt that the man with forethought in this matter will build well in other respects?

If lumber is roughly bulk-piled awaiting construction it does not have a chance to dry off quickly after rains; it should be given at least as good protection as brick and other materials.

Moisture Within the Wood

WELL-SEASONED LUMBER, along with the proper foundations and framing, is essential to good building. Everyone knows this, yet the fact that the home builder does not stand on his knowledge works strongly against his getting what he should have. Many suppose that the dryness of lumber is a matter that must be left to chance. This supposition is highly fallacious. One cannot afford to be unduly fussy in building matters, but neither can he afford not to know what he needs and how he can get what he needs from one source or another.

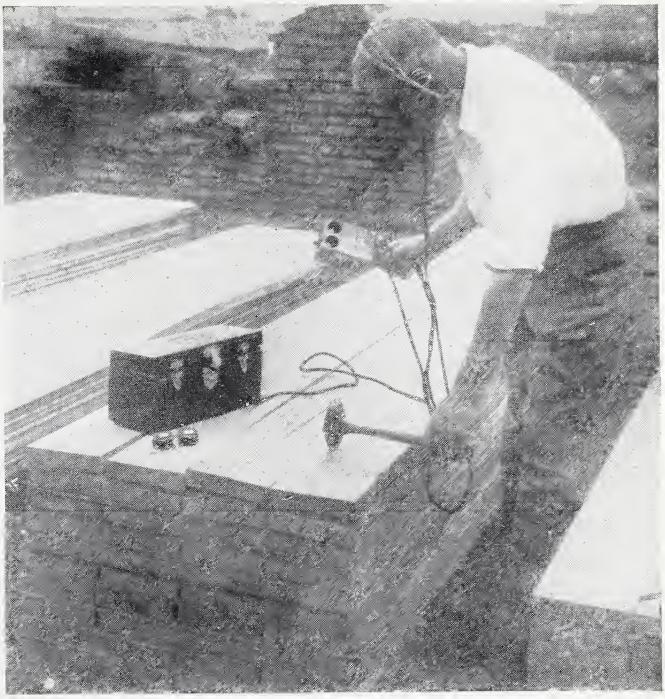


Unseasoned framing lumber warps on the building site; or worse, within the wall. The cheaper green lumber is more expensive in the long run.

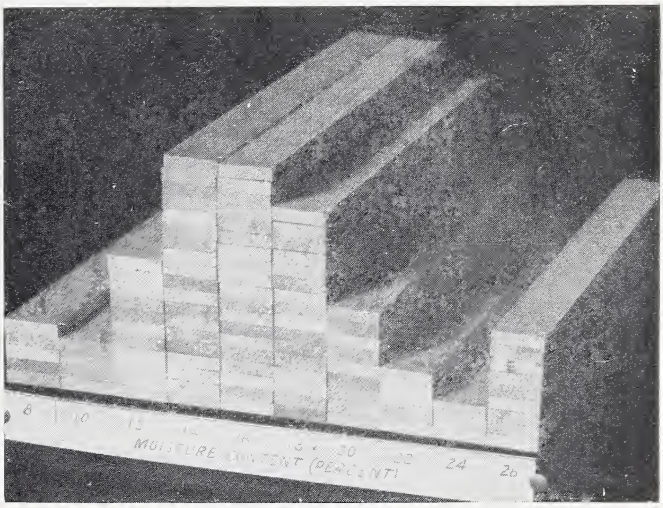
Sheathing put on green may shrink enough to offset most of its insulating value. Sheathed walls of green lumber tested after 1 month's seasoning had only one-half the stiffness and three-fourths the strength of similar walls of well-seasoned lumber.

Stained lumber is usable or useless depending upon what accompanies the stain. But presence of stain indicates exposure to conditions favorable to decay. If the lumber is moldy, black, and wet—beware! If it is cleanly blued and thoroughly dry the chances are that its strength and stiffness have not been materially impaired. One condition is a sign of longtime neglect; the other merely of short time exposure.

Methods of determining the moisture content or the degree of seasoning of wood are easily available to lumber suppliers and builders. The most modern and instantaneous are electrical, as shown here, but there are other good ways, the oven-dry-weight method being the simplest for the occasional user. The progressive lumber salesman realizes the importance of adequately seasoned lumber and is prepared to furnish it.

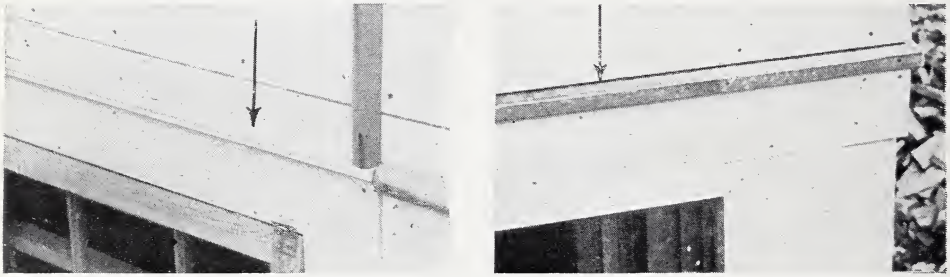


The dryness of the framing and sheathing lumber that is being used in houses under construction, as recently inspected by the Forest Products Laboratory, may be judged from the accompanying illustration. A composite pile of 100 typical pieces is shown, each piece piled according to its moisture content. The bulk of the pieces occur in the 14-, 16-, and 18-percent moisture-content piles. The more there are close to 12 to 14 percent, the better for framing lumber. The less there are at 18 percent or above the better for any purpose. The point is that the market carries both dry lumber and green lumber. Dry lumber gives the best service and is available through reputable builders, dealers, and sawmills.

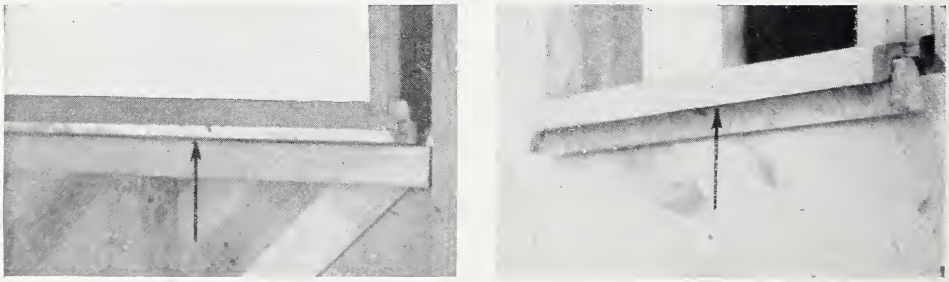


Seeping Moisture

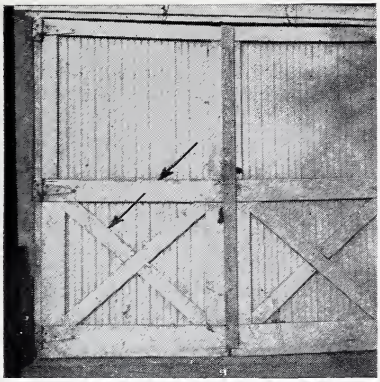
A SOUND ROOF is essential, but the good builder keeps moisture from stealing into the side of the house as well. Any horizontal projection, big or little, acts as a dam to run-off water unless it is built so that the water will go over the top. Nothing is more hazardous than the backing up of water that cannot readily get out. If a horizontal piece must be attached to the surface of the house, then use only decay-resistant wood and overlap the horizontal piece or put on a flashing.



Weak spots in a house are the door and window frames because they penetrate all the protective layers and impart a crosswise obstruction to the downhill flow of water. A frame that does not pitch away or have its top overlapped by the siding (left) is sure to cause trouble. The minimum that should be tolerated is a well-pitched cap made from decay-resisting heartwood; but flashings are the approved method of diverting moisture over openings (right). Properly installed, a good metal strip overlies the pitching drip cap and extends up behind the siding for a short distance. The first cost of good flashings is considerable, but in the end they save far more costly repairs.



A simple metal apron set under the window frame shunts away moisture leaking through and around the window sill. The apron costs little, does not show in the finished building, and is distinctly worth while. On the inside, the apron is turned up (left), and on the outside down (right), so that any moisture that gets in must get out.



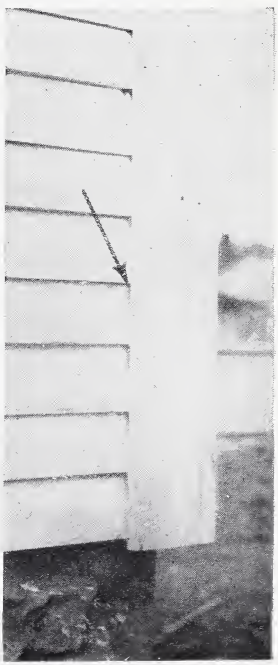
Battens and cross rails on garage doors (left) and other exterior trim features hamper the free drainage of rain water and create a decay hazard.

Correct design and construction eliminate obstructions to the free drainage of water, even on the concrete floor (right).

THE MOST highly decay-resistant woods are not really essential for house siding and trim if the detailed design is such as to guarantee free drainage. But since superior painting characteristics often accompany high decay resistance, it is frequently desirable to use such woods for their combined qualities.

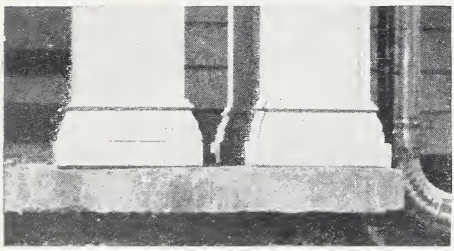
Sapwood of all species is low in decay resistance. The extra cost of a decay-resistant wood for corner boards (left) is partly wasted if sapwood (the light-colored wood on the inner edge) is used, especially if moisture pockets are set up by the design, as in the moldings across the bottom.

Placing corner boards over drop siding (right), instead of fitting the siding against the corner board, leaves openings where rain will beat in and be slow to dry out. Paint and decay troubles are very likely to follow.

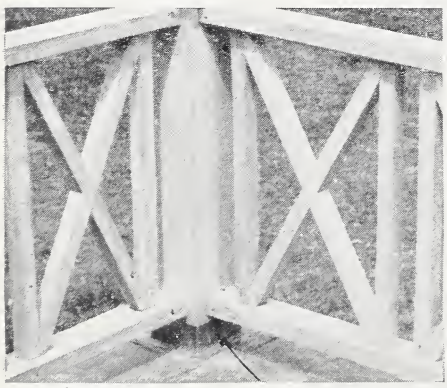


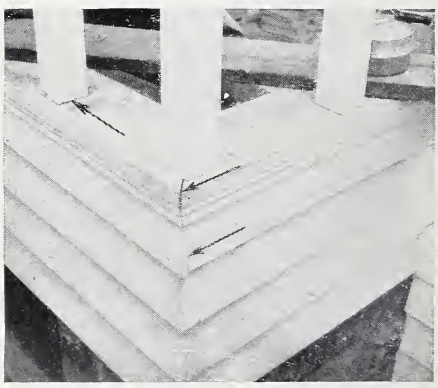
Drainage Outlets and Ventilation

THE PORCH and doorway are vulnerable points in any house and with any kind of building material. If the construction is such that water gets behind the covering or underneath columns, drying out slowly, freezing, pushing, and heaving, the structure rapidly disintegrates—in the case of wood largely through decay or termite attack. Keep the water on the run! Avoid, too, dirt-filled or closed-in space under porches, which invite attack from decay and termites. Ventilation and screening at the sides of unexcavated porches should permit of periodic inspection.



Too often the builder ignores the hazard of porch columns in contact with concrete or other materials (left) and the need for proper draining and ventilation at such points. A metal stool under porch columns is well worth while. In the latest form (right), the column is raised from the concrete, the edges are sloped, and openings provide ventilation.

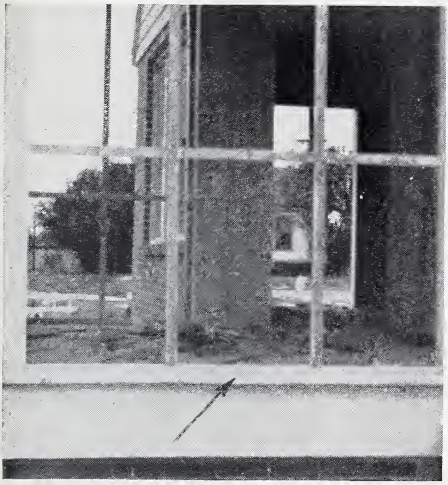




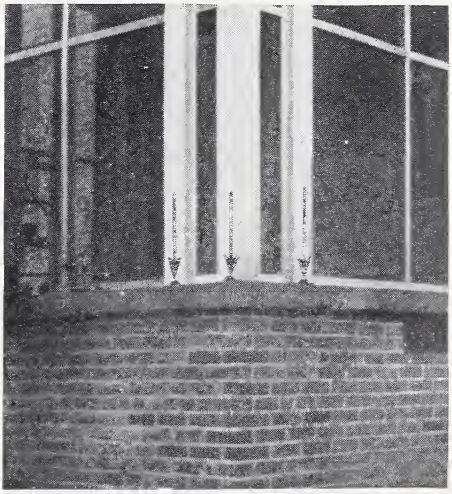
Balustrades, well capped at the top to shed rain, should be of all-heart stock of decay-resistant or specially treated wood and have as few joints as possible. Flashings used to protect the bottom of the posts (left) should be let into the surface so that the water will not run down behind them. Porch posts should rest on pitched rather than on flat surfaces. Open joints in the cap, especially when extending under the posts (right), permit water to drain into rather than away from the woodwork. Butt in place of miter joints in siding expose end grain and add to the hazard.

The principles of good construction violated here (left) include wall sheathing (a), sill, and porch column (b) in direct contact with the ground—all ultimately concealed.

Here (right) the siding comes down so close to the ground that a little accumulation of grass and leaves soon creates a distinct decay hazard.



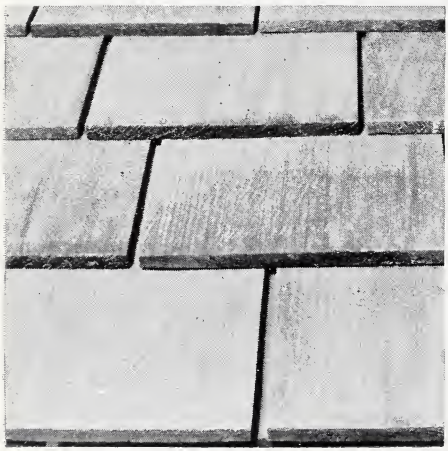
The bottom of screens resting directly on a porch floor creates a decay hazard in frames, floor, and posts.



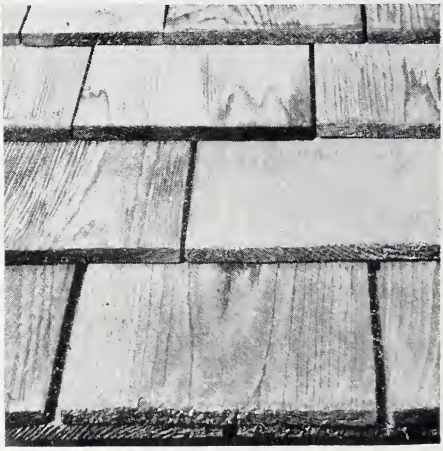
Tunneled holes through the base of posts (right) and also through the bottom rails of screens permit free drainage of water and aeration of the wood.

Roofing Material

THE ROOF is one of the less showy parts of a house, but about the most important. Here false economies are disastrous. There is much difference of opinion as to the most satisfactory kind of roofing. No one roofing material meets all conditions perfectly. Although the fire hazard is one of the factors in controversy, official statistics show that many more fires originate inside the house than on the roof. Within the primary fire zones of congested areas, municipal building codes may prevent the use of wood; but where such restrictions do not apply, wood shingles were found to be the prevailing roofing material. Regardless of advantages and disadvantages of different types, this definite recommendation stands out: Whatever type of material is used it should be the best of its kind. In wood, use edge-grain, all-heartwood shingles instead of flat-grain for permanent roofs, especially for dwellings, because of their much lower tendency to curl and split, their lower shrinkage, and better weathering characteristics. The lower grades of wood shingles for roofs on either high-cost or low-cost houses are not economical in the long run. They are well adapted, however, to use on side walls and on temporary buildings.



Edge-grain shingles are readily identified by their "wire-grain" figure (left). The No. 1 grade recognized in commercial standards admits only such shingles.



Flat-grain shingles have a figure made up of comparatively wide irregular bands (right). Such shingles and those with varying amounts of sapwood are found in all grades below the No. 1 grade of commercial standards.

Roof Protection

SECOND ONLY to the choice of roofing material of the best quality is the importance of proper construction. Well-flashed valleys are essential to nonleaking roofs. Leaks originating in valleys are difficult to locate and expensive to repair. Gutters and downspouts must be sufficient in capacity and provided with adequate outlets. The same rule applies on the roof as in other parts of the house—water must not be allowed to stand on, in, or under wood construction.

Good valley flashing should extend outward well on each side from the center line—not less than 7 inches when the pitch is one-half or greater and not less than 10 inches when the pitch is less than one-half.

Omission of gutters and downspouts, either for architectural effects or for minimizing first costs, increases the hazard of paint troubles, decay, and damp basements. Utility should not be sacrificed to appearance or false economy.

Quality Lumber

Actual dressed thickness, grade with respect to knottiness and soundness, and dryness should all be considered when buying construction lumber. Considerable lumber of less than standard thickness is going into new houses in some localities. Sheathing boards for walls, floors, and roofs are found to be three thirty-seconds of an inch and wall studding one-sixteenth of an inch thinner than the size officially recognized in American lumber standards. Rigid construction can, of course, be obtained with lumber thinner than the standard sizes if special precautions are taken. In fact, a house undoubtedly can be built using thin lumber and special framing methods that will be stiffer than one using standard thicknesses and ordinary construction methods. Such a house, however, will probably be no less expensive. In the usual absence of special methods, substandard sizes cannot be used without a reduction in the rigidity of a house with consequent increased costs of upkeep.

In floor panels the difference between the standard and substandard board thicknesses referred to affects the stiffness of the final floor system about the same as cross bridging between the joists, which few builders would think of omitting. In wall panels the difference between standard and substandard board thicknesses shows up principally in the fact that the thinner material warps and splits more than the thicker. Use of substandard sizes saves little in the initial cost of the house and results in maintenance costs out of proportion to the original savings.

Tests at the Forest Products Laboratory establish principles of proper use of wood in house construction

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